# Low-cost Motorized Microscope Stage

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## ABSTRACT

The use of microscopic **serial imaging and stitching** is a common practice used in laboratory settings to conduct research and contribute to academic experience. Said processes can be time consuming and tedious when done manually. Moreover, motorized microscope stages allow for a **streamlining of this process and more efficient use of materials**, but they are very **expensive** to purchase commercially. Creating a low-cost motorized microscope stage or mechatronic system for stage attachment would allow for more experimental throughput and expand on the potential of microscopy. The proposed device is a **mechatronic system that attaches to the translational control knobs** of a UW-Madison BME Shared Lab microscope via set screws. The design consists of a **custom gear-grip system driven by two gear-reduced stepper motors**. These are mounted to the existing stage, with a control architecture implemented on an Arduino. The Arduino microcontroller provides systematic and calculated **control of the microscope stage in both the x- and y-directions** via sequential pulses and delays.

## PROBLEM STATEMENT

Design Motivation:

- Motorized stages allow for increased **laboratory efficiency**
- Such commercialized stages are **expensive** and **impractical**
- Inexpensive stage would allow students to save time and gain image consistency without financial commitment

Objective:

Design and fabricate a microscope stage or mechatronic system that allows for **stage motorization and automation of imaging processes** used in the UW-Madison BME Experimental Teaching Lab.

## BACKGROUND

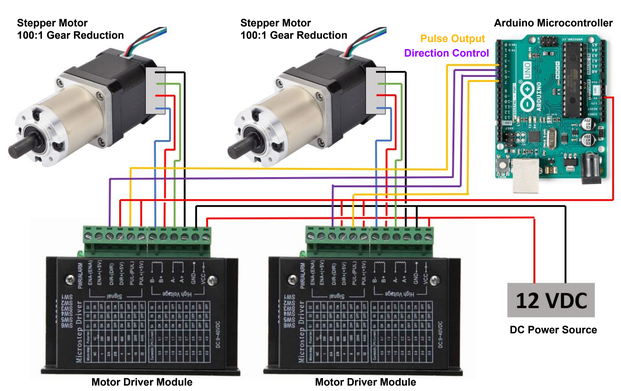
*[Figure 1] Nikon TI-U Inverted Fluorescence Microscope [1]*

- **Serial Imaging** is used to capture sequential images of a specimen
- Serial images can be **stitched into a singular image** using ImageJ
- Researchers can automate serial imaging using **Micro-Manager** (open-source) and a motorized stage [2]
- Industrial systems from **Prior and ASI** are expensive
- Cells span diameters of 10s of microns

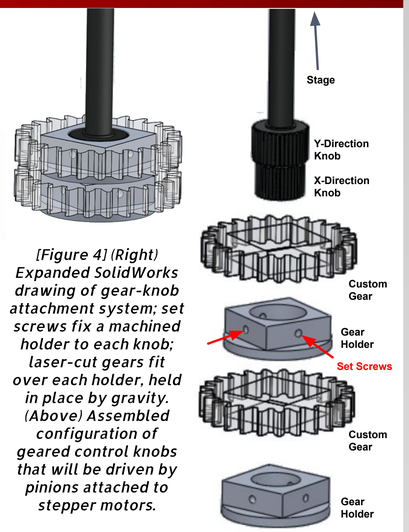
## DESIGN CRITERIA

- Motorized mechanism to move the microscope stage
- Controls the stage movement in the x- and y-directions
- The designed system is **removable** from the microscope
- Maintain a resolution of **1 micron**
- Remain within a budget of **$100**

## COMPONENTS




*[Figure 3] (Above) Wiring diagram of mechatronic system for driving two 100:1 gear reduced stepper motors ; each motor driven by a stepper motor driver modulating power from a 12V source according to pulse and direction input from an Arduino Uno [3].*



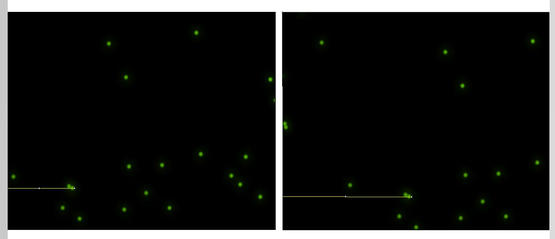

*[Figure 4] (Right) Expanded SolidWorks drawing of gear-knob attachment system; set screws fix a machined holder to each knob; laser-cut gears fit over each holder, held in place by gravity. (Above) Assembled configuration of geared control knobs that will be driven by pinions attached to stepper motors.*

## TESTING

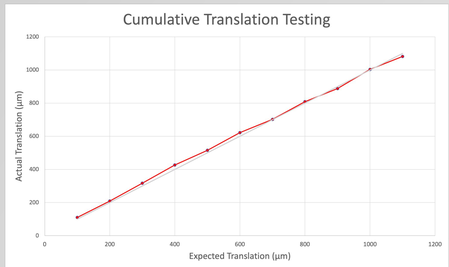
- Tested entire **system in series**
- Input desired (100$\mu$m) translation
- Measured actual translation using consecutive imaging of fluorescent microspheres and Image J analysis (see *Figure 7* for details)
- Cumulative **1.6% error** over 1100$\mu$m

*[Table 1] Summary Statistics*

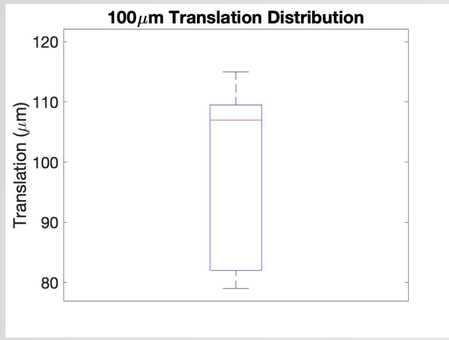
| **Mean ($\mu$m)** | **SD ($\mu$m)** | Min ($\mu$m) | Max ($\mu$m) | Median ($\mu$m) |
|---|---|---|---|---|
| **98.4** | **14.1** | 79 | 115 | 107 |



*[Figure 7] Fluorescent microspheres imaged before (left) and after (right) intended 100$\mu$m translation. Yellow lines drawn to measure actual distance traveled.*




*[Figure 6] Actual translation of stage with 100$\mu$m inputs compared to the expected translation. Grey line indicates precision, red line indicates actual stage movement.*




*[Figure 8] Visual demonstration of the 100$\mu$m translation data presented in a box and whisker plot.*

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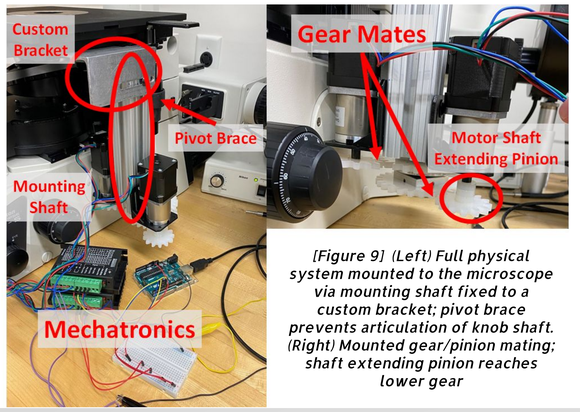
## CURRENT DESIGN




*[Figure 9] (Left) Full physical system mounted to the microscope via mounting shaft fixed to a custom bracket; pivot brace prevents articulation of knob shaft. (Right) Mounted gear/pinion mating; shaft extending pinion reaches lower gear*

## DISCUSSION

- Design efficacy and **proof of concept**
- Current design makes automated stage translation more accessible to those with dexterity deficits
- The budget totalled **$129.85**
- Design is only applicable to this microscope model but can be modified via open-source CAD drawings
- Consideration of component longevity
- More testing and fabrication necessary to determine **lowest resolution** that the design can achieve

## FUTURE WORK

- Address software shortcomings of design
  - **No image automation**: only Arduino to motor control
  - Reverse logic: PC to Arduino through MicroManager
- Integrate a **Motion Control Device** into the system
  - Necessary for autonomous operation
- Refine the mounting apparatus
  - Smaller gear teeth
  - Lighter weight
- Make all CAD drawings and code **open-source** and progress toward publishing in *Biomed Eng Educ*

## REFERENCES

[1] Nikon.com. 2020. Nikon | Healthcare Products & Solutions (Microscope Solutions) | Inverted Microscopes. [online]
[2] Micro-manager.org. 2020. Micro-Manager. [online]
[3] DroneBot Workshop. (2019, May 25). Using BIG stepper motors with Arduino. Retrieved December 3, 2020, from Dronebotworkshop.com website: https://dronebotworkshop.com/big-stepper-motors/